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ORIGINAL ARTICLE

Land use and cover change in Japan and Tokyo's appetite for meat

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Abstract Urban consumption of ecosystems services such as food generates environmental impacts at different geographical scales. In the last few decades Tokyoites have shown an increasing appetite for meat. This study examines the environmental implications of Tokyo's increasing meat consumption by analyzing how this trend has affected land use and cover change in areas near and far away. Historical databases (1970–2005) are employed in order to explore meat consumption patterns in Tokyo and to relate it with beef and pork production in areas within the country and abroad. It also integrates the historical analysis of production and consumption patterns with a discussion of the drivers (e.g., wealth, price, policies and seafood availability) behind these trends. We identified that meat production in Japan followed three distinct phases between 1877 and 2005. In the first period it took 50 years for production to increase by 50%, while during the next phase production showed the same growth in just half the time. Major changes in land use/cover change because of domestic meat production occurred mainly during the second phase and, thereafter, when domestic production declined and was substituted to a great extent by imports. Despite the increasing consumption of imported meat, Tokyo relies greatly on domestic meat produced in its neighboring prefectures. The paper concludes that regional planning can be used as an effective instrument to protect the environment and secure protein for the population of mega-urban areas such as Tokyo.

Keywords Meat consumption · Land use · Japan · Tokyo

Introduction

The inclusion of meat[1] in the early human diet is regarded as a fundamental adaptation that led to different sorts of developments (e.g., of tools, social interaction, communication, etc.), one of which was new patterns of land use (Stanford and Bunn 2001). From scavenging and hunting, human practices evolved to domesticating animals for meat production.

Industrial agriculture allowed for the increase in production and widespread consumption of meat worldwide. In the past 40 years, per capita meat consumption increased globally by 60%. These trends have been facilitated by a package of interconnected factors that includes globalization, increase in wealth, urbanization and, until very recently, decrease in prices. But while the so-called livestock revolution has been important for the provision of animal protein to the increasing human population, more land is directly and indirectly (i.e., for feed production) required to produce meat (Clay 2004).

[1] By meat we mean terrestrial animal carcasses used as food.

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Japan is among the world's largest importers of meat. After World War II, its appetite for meat increased quickly despite its longstanding love for seafood. Tokyo,[2] Japan's largest city, houses an affluent population of over 8.5 million people (as per 2005), and every day an enormous amount of food flows into Tokyo to feed this population. Among the different kinds of meat, pork, chicken and beef are those most prevalent in Tokyo's menus. As a "global city," Tokyo is connected internationally through trade and investment networks and relies heavily on imported meat. Nevertheless, Tokyo still counts greatly on its surrounding prefectures for its meat supply.

Urban populations are currently the largest consumers of meat, but few studies have thus far analyzed the impact of urban consumption patterns on ecosystem services and how this affects land use and cover change (LUCC) at multiple scales (local, regional, global) and over time. It should be noted here that livestock production is one of the most significant agents of direct and indirect land use change. LUCC can have significant environmental impact, as will be discussed in the following section. Understanding the trajectory of meat consumption in large urban areas and its driving forces can help promote policies that have less detrimental impact on land use and cover. It can also shed light on environmental impacts connected to LUCC.

We took advantage of different time series (1970–2005) produced by the Tokyo Metropolitan Government (TMG) and the Ministry for Agriculture, Forestry and Fisheries (MAFF) to analyze how Tokyo's consumption of beef and pork impacts LUCC within the country. We accounted for the direct land used for livestock production in Japan (i.e., grazing and farm land). This paper starts with a summary of the main environmental impacts related to livestock-induced land use change ("Meat production, land use change and environmental impact"). "Historical analysis" explores the historic trends of meat consumption and production both within Japan and Tokyo. The methodology we employ in order to calculate the area directly needed to support Tokyo's meat consumption is outlined in "Methodology," while the main results, regarding the provision of meat (beef and pork) in Tokyo through its wholesale and retail markets, are presented in "Results." This part also describes the most important geographical regions that arrange for the meat arriving at Tokyo's wholesale market and quantify the amount of land directly appropriated in different regions of Japan to produce the meat that has been consumed in Tokyo. Finally, we discuss the main results in line with certain relevant statistics that have been collected from a multitude of sources.

[2] By Tokyo we mean Tokyo's 23 wards.

Meat production, land use change and environmental impact

Livestock production has been identified as having a major impact on the environment. Steinfeld et al. (2006) conducted a comprehensive review of the academic literature and found that livestock production can trigger greenhouse gas (GHG) emission, air pollution, water depletion, water pollution and biodiversity loss among others. These impacts can be direct (i.e., from activities relevant to livestock rearing) or indirect (e.g., from agricultural activities relevant to the production of the feed required by the livestock). A large number of these impacts can be linked to the conversion of land for pasture and cropland for the feed required to feed the animals. Considering that the main theme of this special issue is land use change, the environmental impacts that will be discussed in this section will be linked to direct and indirect land use change.

According to Naylor et al. (2005), livestock is currently the world's single largest appropriator of land, with land dedicated to the production of feed crops overtaking grazing land. It is expected that the demand for meat will increase in the future (Steinfeld et al. 2006), something that will most likely result in an increasing appropriation of land for housing and feeding these animals. Galloway et al. (2007) suggest a 4:1 ratio between the land required to produce animal feed and human food, with this ratio bound to increase. What is more important, however, is that there has been a shift towards an industrial production mentality. This has resulted in the "*delinking of livestock from the supporting natural base*" (Naylor et al. 2005), which is particularly true for meat- and feed-importing countries such as Japan. Galloway et al. (2007) calculated that the consumption of pork and chicken meat in Japan appropriates around 2.2 million hectares of land abroad, an area that is equal to approximately half of the total available arable land in Japan.

Direct and indirect livestock activities are responsible for a large fraction of the GHGs emitted globally every year. Steinfeld et al. (2006) calculated that livestock production and related activities might be responsible for 9% of the total anthropogenic CO_2 emissions and an impressive 35–40% of CH_4 and 65% of N_2O emissions. A significant fraction of these emissions is due to direct land use changes for pasture, such as deforestation, and indirect land use changes relevant to feed production. The subsequent degradation of land is another important factor that cannot be underestimated. In particular, livestock-related land use changes are responsible for emitting 2.4 billion tons of CO_2 per year globally, 0.03 billion tons CO_2/year from livestock-related cultivated soils and 0.1 billion tons CO_2/year from livestock-induced desertification. These CO_2 emissions that are attributed to land use changes are responsible

for about 35.8% of all GHGs emitted by livestock production globally (Steinfeld et al. 2006).

Livestock-induced land use change also has a significant impact on biodiversity. Generally speaking, increasing levels of livestock production can be detrimental to biodiversity with deforestation, habitat fragmentation and land use intensification being the leading land use-related causes (Steinfeld et al. 2006). Wassenaar et al. (2007) predict significant deforestation in the Brazilian Amazon, which might be attributed to livestock production (both directly and indirectly).

Another environmental impact of livestock production that can be linked to the loss of biological diversity is the effect of grazing and land use change on the water cycle. Extensive grazing may result in a changing plant composition, which in turn might be unable to slow down runoff, resulting in altered water flows. This can affect streams and riparian ecosystems (Belsky et al. 1999). Additionally, livestock-induced land use conversion can also affect water flows at the basin level with the Mississippi River Basin being an example (Zhang and Schilling 2006).

There are several additional environmental impacts with indirect links to land use change that we do not discuss here. The interested reader is directed to Steinfeld et al. (2006) for an extensive review of the existing literature.

Historical analysis

Despite the scarcity of land, about two-thirds of Japan is covered by forests, a figure that has remained constant for more than 4 decades. One of the reasons why Japan could keep the integrity of its forests is that its ecosystems have never faced significant pressure to produce livestock, whose demand for grazing (especially in the past) could have been a strong competitor for forest cover. While meadows and pastures covered one percent of Japan's area between the mid-1960s and the mid-1970s, this area shrank and constituted only 0.2% of Japan in 2004 (MIAC 2008a, b). Therefore, significant direct land use/cover change in Japan as a whole cannot be attributed to the changes in meat production in the last few decades.

A reason why Japan could avoid the possible downside of meat production is because, driven by Buddhism, the country abandoned for centuries the habit of meat eating. Emperor Tenmu, in 676 A.D., was the first of subsequent emperors to ban meat consumption (Otsuka 1996). During the ban period, which lasted until the end of the Tokugawa Shogunate in 1867, both meat eating and activities related to the slaughtering of animals were considered as impure. While meat eating has lost its impurity connotation, butchery remains an activity facing discrimination (Sakurai 2004). Ten years after the end of the ban, 34,000 cows were slaughtered for meat, while a 100 years later this number rose to 750,000, as will be discussed later. Despite the relatively low consumption of meat by the Japanese, which has been attributed to high prices (Hayami 1979), there has been a continuous growth of the Japanese livestock industry since the ban was lifted. This has been supported by both increases in the efficiency of the domestic meat industry as well as by the increasing importance of imports to accommodate the demand by an increasingly affluent Japanese society.

Following the end of the World War II, meat prices skyrocketed and, as a result, the daily per capita intake of meat in Tokyo was a mere 5 g/capita/day in 1947. However, once the Japanese economy started to flourish, consumption of meat in Tokyo increased gradually, achieving its peak in the late 1970s (88 g/capita/day). After that, meat intake, driven by stabilized beef consumption, leveled off despite the continuous increase of pork consumption. Tokyo's residents have historically consumed, on average, more meat than the average Japanese citizen (up to 250% more in the late 1940s). However, this difference had disappeared by the mid-1980s, as is shown in Fig. 1. Considering Japan's population and affluence, these figures are still not impressive by western standards, and Japanese meat consumption has been considered relatively shy among developed countries.

This increasing prominence of meat in the Japanese diet is a result of a shift in dietary preferences that becomes more apparent when comparing food intake across generations. Although fish intake remains high for all age groups, youngsters and young adults (especially between the ages of 15 and 39) are eating, on average, more meat than older generations (TMG 2007). This is arguably due to a change in consumption patterns of younger generations,

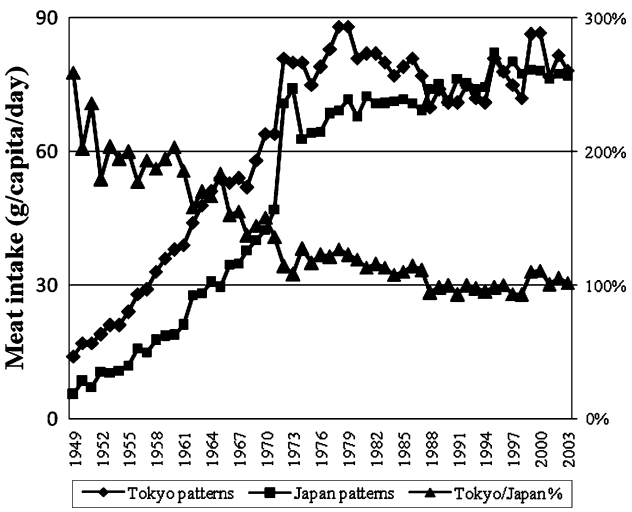

Fig. 1 Meat for Japan and Tokyo and percent difference. Source: MIAC (2008c) and TMG (2007)

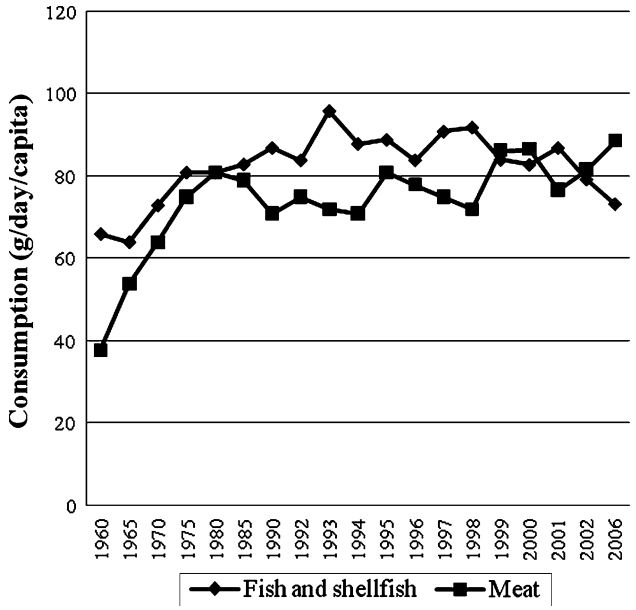

Fig. 2 Meat and fish intake for Tokyo. Source: TMG (2007)

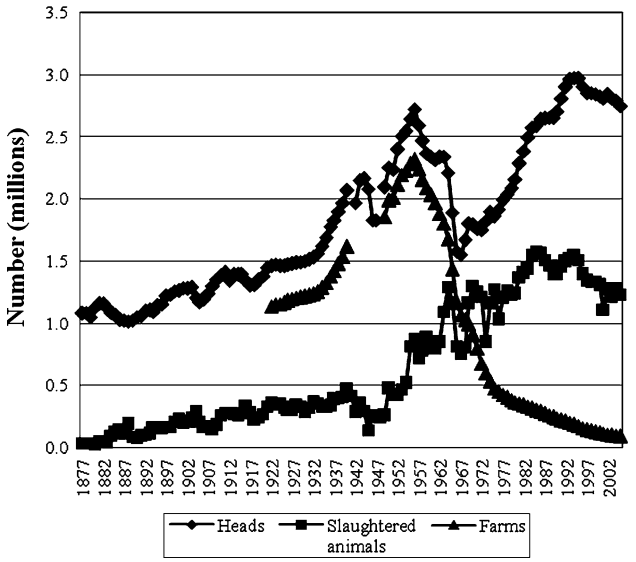

Fig. 3 Number of farms, heads raised and animals slaughtered for beef in Japan (1877–2005). Source: MIAC (2008d, e)

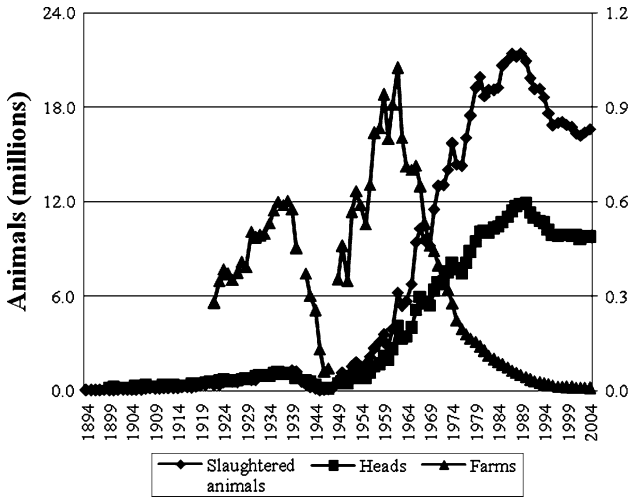

Fig. 4 Number of farms, heads raised and animals slaughtered for pork in Japan (1894–2005). Source: MIAC (2008d, e)

which have adopted a more westernized diet. For instance, in 2006, Tokyo's citizens aged 15–20 years old ate far more meat (148 g/day) than seafood (64.6 g/day). In contrast, senior Tokyoites still preferred the traditional diet based on fish, rice and vegetables. This difference in diet among age groups is noticeable in the gap between the heights of the elderly and the young. In 1989 adolescents were on average 4 inches taller than their grandparents. Consequently, Tokyo's residents experienced in 1999, for the first time in post-war history, an average meat intake that was higher than the seafood intake (refer to Fig. 2).

In order to fuel this increasing demand for meat, domestic production had to increase significantly. Both the number of farms and the number of cattle (for meat purposes) being fed in Japanese farms increased until 1956 (Fig. 3). After that, the number of heads (both of slaughtered animals and animals being raised) declined following the decreasing number of farms, but just up to a point. Following a decade in decline, the number of heads started to increase despite the decrease in the number of farms. Increasing efficiency was fundamental to sustain production and meet the added demand. In 1994 domestic production peaked at the same time as the number of farms decreased by 92% of its maximum point in 1956. This is an indication of a transition towards an industrialized model for meat production. From the mid-1990s, however, the number of heads started to show a slight decline (accompanied by a constant decline in the number of farms), suggesting that increases in productivity may have reached saturation.

Regarding pork, production decreased drastically during World War II, but took off fast once the war was over (refer to Fig. 4). The number of farms raising pigs for meat increased until 1962 when there were 1 million pig farms in the country. After that, the number of farms started to shrink, and in 2006 they were less than 8,000. Despite this decrease, the number of slaughtered pigs started to decline only after 1987. This suggests that for pork, productivity may have reached saturation before it did for cattle.

While meat has become more prevalent on Japanese plates, national policies have attempted to contain this trend. The Japanese Government advocates that the Japanese should shift to a traditional diet. The pro-shift argument was usually based on health concerns, but has recently incorporated the notion of self-sufficiency. The

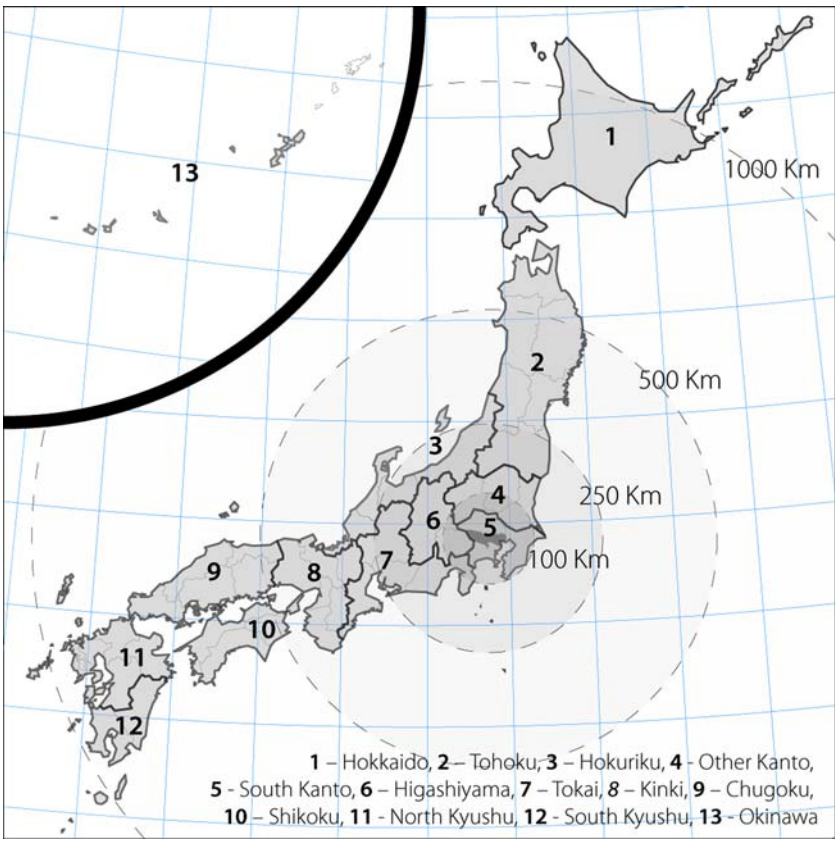

Fig. 5 Map of Japan with the areas considered in our calculations and distance from Tokyo

Japanese Government claims that the country is capable of covering most of its traditional diet, while for the western diet, Japanese self-sufficiency is significantly lower. Part of this campaign is the dichotomy between fish, symbolizing the Japanese diet, and meat becoming a symbol of the west (MAFF 2006d). However, despite this effort, huge amounts of meat are imported every year to meet the domestic demand, and as a result Japanese self-sufficiency for beef and pork has been steadily decreasing since the 1960s (refer to "Discussion").

Domestic and imported meat arrives in the major urban centers of Japan through either the retail or the wholesale channel of distribution. In Tokyo, the Tokyo Metropolitan Government (TMG) manages all wholesale markets within the city, as per the Central Wholesale Market Law (enacted in March 1923 and revised in April 1971). Through this law the TMG is mandated to ensure the stability and safety in food supply for Tokyo (Bestor 2004). Out of the 11 wholesale markets within the city, only one, Shokuniku, handles meat.

Wholesale markets have been decreasing in importance as the main distribution channel for food, but that is not particularly true for domestic meat. For example, all of Japan's wholesale markets sold 39.6% of the domestic beef carcasses in 2005 (up from 20.3% in 1970) and 17.7% of pork (up from 13.7% in 1970). Nevertheless, only a relatively small amount of already cut and processed meat is being sold by wholesale markets, not to mention the imported meat that is almost entirely sold through the retail sector. As a result, along the years, the retail sector has been able to overtake the wholesale, buying directly from domestic and international producers and middlemen. Reducing prices has been the core of this shorter distribution system.

Methodology

The total amount of domestic beef and pork consumed within Tokyo was calculated as the sum of the wholesale and retail market sales in the city. The amount of meat entering Tokyo through the wholesale market was obtained from (TMG 1971, 1976, 1981, 1986, 1991, 1996, 2001, 2006a). This dataset contains the value (in yen), the amount of meat by type of animal (in kg and heads) and the Japanese prefecture of origin. In order to facilitate the analysis, the 47 Japanese prefectures were aggregated into 13 regions, as shown in Fig. 5, namely Hokkaido, Tohoku, Hokuriku, South Kanto, Other Kanto, Higashimaya, Tokai, Kinki, Chugoku, Shikoku, North Kyushu, South Kyushu and Okinawa.[3] The amount of that meat that actually

[3] South Kanto includes Saitama, Chiba, Tokyo and Kanagawa. Other Kanto includes Ibaraki, Tochigi and Gunma.

remained within the city was calculated from the fraction of meat sold by the wholesale market that ended up within the 23 Tokyo wards as reported by (TMG 2006b). It is worth mentioning here that the fraction of domestic meat sold by the wholesale market and actually remaining within the 23 wards dropped from 79.1% in 1970 to 56.4% in 2005.

In order to calculate the amount of meat sold by the retail market for consumption within Tokyo, and considering the lack of appropriate data, a more indirect route was adopted. In a nutshell, the retail market quantity was calculated as the residual of the overall meat consumed by Tokyo residents minus the meat sold by the wholesale market, minus the imported meat (sold by both wholesale and retail markets). The overall amount of meat consumed for food was retrieved from the Food and Agriculture Organization's (FAO) food balance sheets (FAO 2008). Given that this figure represents the Japanese average, the FAO figures were modified accordingly in order to represent the specific meat consumption patterns of Tokyoites. The correction factor was equal to the percent difference between the meat intake of Tokyo residents and the Japanese residents as reported by TMG (2007) and MIAC (2008c) and discussed in Fig. 1. Additionally, the FAO reports food consumption data until 2003; therefore, consumption for the year 2005 was considered as being equal to that of the last year reported. Statistics on imported meat for the whole of Japan were collected from (FAO 2008; MAFF 2007).

Tokyo experiences a population increase during daytime as residents from neighboring cities and prefectures commute to the city's 23 wards for working and studying purposes. In order to accommodate the effects of commuters in the overall demand for meat within the city, the total "eating population" was considered in our calculations. "Eating population" was equal to the commuting population divided by two plus the night time population. The commuting population was divided by two to allow for the fact that commuters probably have one of their two main daily meals that are likely to contain meat (lunch or dinner) in Tokyo. The Tokyo daytime and nighttime population was retrieved from (MIAC 2008f, g).

Time series for the total land required to raise the livestock produced in Japan were collected from statistics provided by the Japanese Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF). In more detail, two different datasets were utilized. The first dataset contained information on the farm enterprises in the animal industry such as the number of farms by type of animal raised, prefecture of location, area and the number of animals being raised at a given point in time (MAFF 1971a, 1976a, 1981a, 1986a, 1991a, 1996a, 2001a, 2006a). This dataset, however, did contain information regarding only the major farms responsible for raising around 95% of domestic beef and 99% of domestic pork. In order to account for the total production of meat, heads-to-hectare ratios for each animal and prefecture were calculated for the years 1975, 1980, 1985, 1990, 1995, 2000 and 2005. The observed trends were then extrapolated for 1970 and are discussed in greater detail in the ensuing section. These calculated head-to-hectare ratios together with figures on the amount of hectares required to produce 1 kg of meat (ha-to-kg ratios) have subsequently been applied (not directly though) to quantify the total land required to raise the animals consumed by Tokyo residents. More specifically, they have been combined with another dataset that contained the total amount of farms and number of animals produced during these years in Japan (MAFF 1971b, 1976b, 1981b, 1986b, 1991b, 1996b, 2001b, 2006b).

The main reason that prohibited the direct application of these ratios to calculate the total direct land appropriated for Tokyo's meat consumption (from domestic sources) is the fact that livestock do not stay exactly a year in the farm. Pigs stay on average less than a year, while cattle more than a year. Applying directly the aforementioned ratios to the total amount of meat consumed in Tokyo would result in an overestimation of the direct land required for pork production and in an underestimation of the direct land for cattle. In order to circumnavigate this difficulty, we estimated the ratio of the livestock present in the farms at any given moment (as reported by the Census) that will end up in Tokyo. This fraction was calculated by dividing the amount of meat consumed (by prefecture of origin) by the total amount of animals produced in each prefecture (as reported in slaughtered animals statistics). This figure was then multiplied by the number of animals present in the farms at any given point (as reported by the census). Finally, this figure was multiplied by the kg-to-hectares ratios in order to calculate the amount of direct land required in each prefecture to provide for the meat consumed in Tokyo.

Results

Our results account for changes in production of meat and the land required to raise the domestic livestock ("Production of meat and land use"), changes in the amount of meat entering Tokyo though its wholesale and retail channels of distribution ("Wholesale market" and "Retail," respectively) and changes in the amount of land directly appropriated by Tokyo's appetite for beef and pork ("Land use"). These results were calculated for both Japan as a whole and by region of production within the country. Detailed data summarize our findings for the different

regions of Japan for 1970 and 2005 regarding changes in production of meat and the land required to raise the domestic live-stock (Tables 1, 2). Additional data provided in the electronic supplementary material presents the summary of the changes in the amount of beef and pork entering Tokyo though its wholesale market (Tables 1, 2, supplementary material). More detailed data covering all regions of Japan from 1970 to 2005 are also provided in the electronic supplementary material for "Retail" regarding total direct area required to raise the domestic beef and pork consumed in Tokyo (Tables 3, 4, supplementary material) and the percentage of domestic farm land appropriated for producing the beef and pork consumed in Tokyo (Tables 5, 6, supplementary material).

Production of meat and land use

Generally speaking, the direct amount of land required for domestic livestock production has been steadily decreasing in Japan as a whole since 1970. There has been a decrease of that area by 63.3% for beef (from 706,800 hectares in 1970 to 259,300 hectares in 2005). The decrease for pork is even greater (92.3%), from 134,800 hectares to 10,400 hectares. This decreasing amount of direct land allocated for raising

Table 1 Key statistics for domestic beef production in 1970 and 2005 by region

	Heads (1,000 heads)		Percent diff. (%)	Area (1,000 ha)		Percent diff. (%)	Heads/ha		Percent diff. (%)
	1970	2005		1970	2005		1970	2005	
Hokkaido	25.1	266.7	961.1	32.2	91.9	185.1	0.8	2.9	272.1
Tohoku	266.8	310.1	16.2	178.5	66.6	−62.7	1.5	4.7	211.6
Hokuriku	37.7	20.9	−44.5	13.8	1.5	−88.9	2.7	13.6	398.2
Other Kanto	91.4	157.2	71.9	43.9	9.5	−78.4	2.1	16.6	694.8
South Kanto	29.2	53.8	84.1	5.3	1.1	−79.6	5.5	49.6	802.1
Higashiyama	37.6	25.2	−33	10.2	1.5	−85.4	3.7	17.1	360.5
Tokai	74	123.4	66.6	11.1	2.7	−76.1	6.7	46.4	595.7
Kinki	75	59	−21.3	18.7	2.7	−85.6	4	21.8	445.9
Chugoku	265.9	73	−72.5	114.3	8.4	−92.7	2.3	8.7	274.5
Shikoku	86.8	56.4	−35	23	1.4	−93.9	3.8	39.9	957.9
North Kyushu	289.5	308.4	6.5	115.96	23.86	−79.4	2.5	12.9	417.9
South Kyushu	383.2	439.3	14.6	130.63	42.04	−67.8	2.9	10.5	256.3
Okinawa	22.8	46.9	105.9	9.13	6.22	−31.9	2.5	7.5	202.4
Japan	*1684.9*	*1940.3*	*15.2*	*706.8*	*259.3*	*−63.3*	*2.4*	*7.8*	*227.5*

Table 2 Key statistics for domestic pork production in 1970 and 2005 by region

	Heads (1,000 heads)		Percent diff. (%)	Area (1,000 ha)		Percent diff. (%)	Heads/ha		Percent diff. (%)
	1970	2005		1970	2005		1970	2005	
Hokkaido	205.4	177.5	−13.6	15.2	2.3	−84.6	13.5	75.9	460.9
Tohoku	608.6	391.2	−35.7	24.3	2.5	−89.6	25.0	154.9	519.5
Hokuriku	212.4	108.0	−49.2	6.5	0.5	−93.0	32.7	235.8	621.4
Other Kanto	803.0	808.2	0.7	32.3	1.5	−95.3	24.9	537.7	2061.6
South Kanto	668.4	423.8	−36.6	17.5	0.8	−95.5	38.2	537.1	1307.3
Higashiyama	188.0	67.1	−64.3	3.9	0.1	−96.2	48.3	453.4	838.6
Tokai	564.9	458.8	−18.8	7.6	0.5	−93.7	74.6	966.0	1194.4
Kinki	161.5	39.1	−75.8	1.4	0.1	−94.6	117.6	528.8	349.4
Chugoku	261.9	54.7	−79.1	4.5	0.2	−96.2	58.1	318.2	447.3
Shikoku	222.9	125.6	−43.7	3.0	0.2	−94.2	75.2	726.0	865.5
North Kyushu	402.5	411.1	2.1	9.1	0.7	−92.4	44.2	597.5	1250.4
South Kyushu	297.9	506.5	70.1	6.5	1.0	−84.4	46.1	503.0	991.5
Okinawa	183.0	81.4	−55.5	3.1	0.1	−97.7	58.8	1130.1	1821.1
Japan	*4780.4*	*3653.0*	*−23.6*	*134.8*	*10.4*	*−92.3*	*35.5*	*350.5*	*888.2*

livestock coupled with the overall increase in the production of meat between 1970 and 2000 (refer to the Introduction) means that livestock production has been intensified. An indicator that can clearly illustrate this intensification is the number of animals raised per hectare of available land (heads per ha).

Nowadays, far more animals are being raised per hectare of land when compared to 40 years ago. For example, the number of cattle raised per hectare of land increased from 2.4 in 1970 to 7.8 in 2005 (227.5% increase), while the relevant figures for pork were 35.5 head/ha in 1970 and 350.5 heads/ha in 2005, which corresponded to a massive 888.2% increase. Figures 6 and 7 show the evolution of farm area and heads per hectare since 1970. However, the aforementioned figures denote the averages for Japan and thus hide the distinct patterns encountered within the different regions of the country.

Wholesale market

There has been a significant increase in the amount of beef entering Tokyo through its wholesale market since 1970. In more detail, there has been an increase of 147.5% from 14,200 tons of beef in 1970 to 35,200 tons in 2005 (from a maximum of 36,300 tons in 1995 and 2000). On the other hand, pork landing in Tokyo through its wholesale market decreased by 32.7%. The wholesale market was responsible for providing 18,800 tons of pork in 1970 and 12,600 tons in 2005. It should be noted here that these figures represent the amount of meat actually remaining within the 23 wards of Tokyo. In fact more meat was sold in Tokyo's wholesale market but was funnelled outside the city. The amount of meat that remained within city limits was 79.1% in 1970, 71.2% in 1975, 74.6% in 1980, 68.2% in 1985, 65.2% in 1990, 63.9% in 1995, 59.3% in 2000 and 56.4% in 2005 as reported by (TMG 2006b). The regions of Tohoku and Kanto have traditionally been the main sources of the meat sold by Tokyo's wholesale market. These regions accounted in 2005 for 75.5% of the beef and 96.0% of the pork sold by the wholesale market.

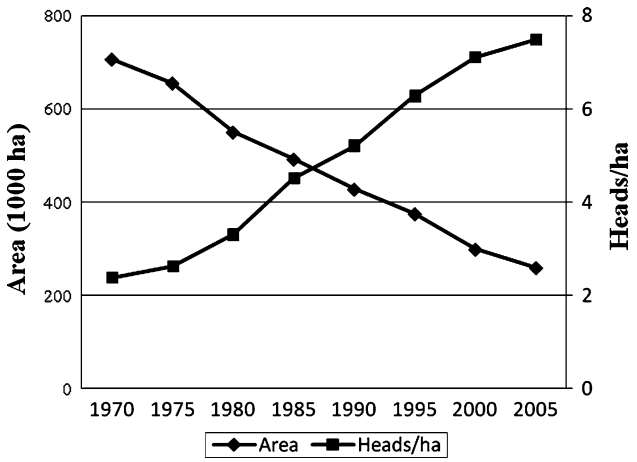

Fig. 6 Farm area for raising beef in Japan and animals per hectare

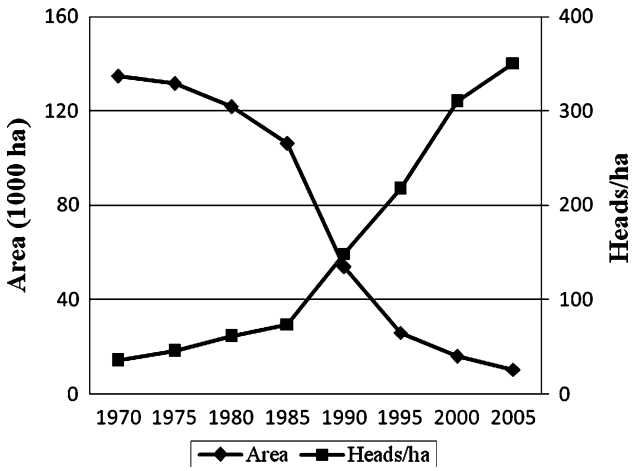

Fig. 7 Farm area for raising pork in Japan and animals per hectare

Retail

As has already been discussed in "Historical analysis," the calculation of the domestic meat entering Tokyo through the retail market poses a great challenge because of the lack of relevant data. Figures 8 and 9 summarize the calculated flows for the overall meat consumed in Tokyo, the imported meat sold in Tokyo, the Japanese meat sold through the wholesale market and the residual, which represents Japanese meat sold through the retail market. Most of the imported meat consumed within Tokyo is sold through the retail market given that only small amounts of imported meat have been reported as being sold through the Tokyo wholesale market (TMG 1971, 1976, 1981, 1986, 1991, 1996, 2001, 2006a)

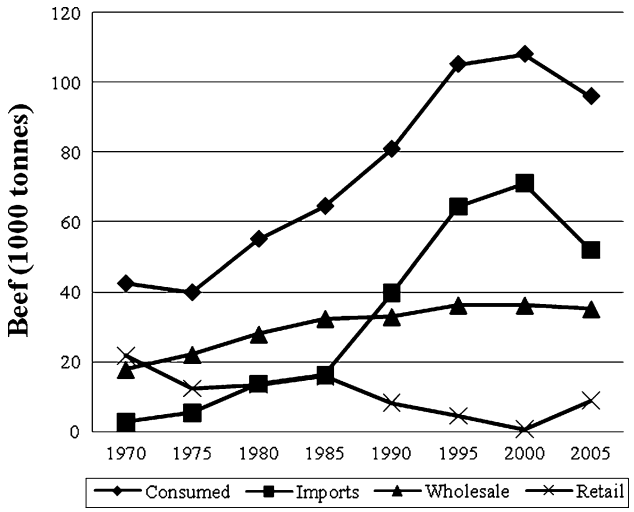

Fig. 8 Overall and amount of beef consumed within Tokyo and avenues of supply

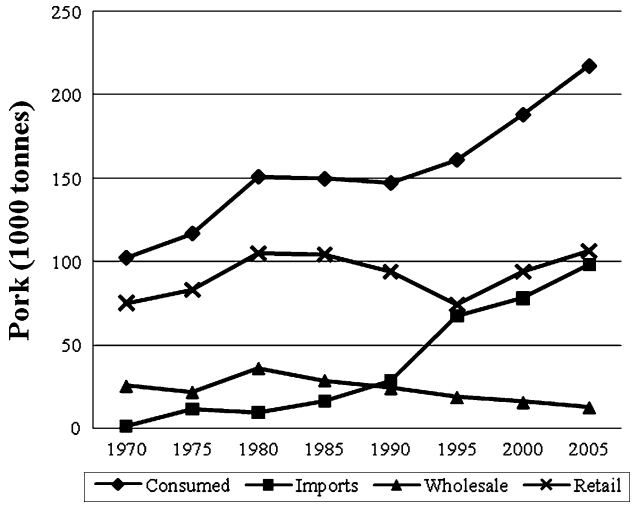

Fig. 9 Overall and amount of pork consumed within Tokyo and avenues of supply

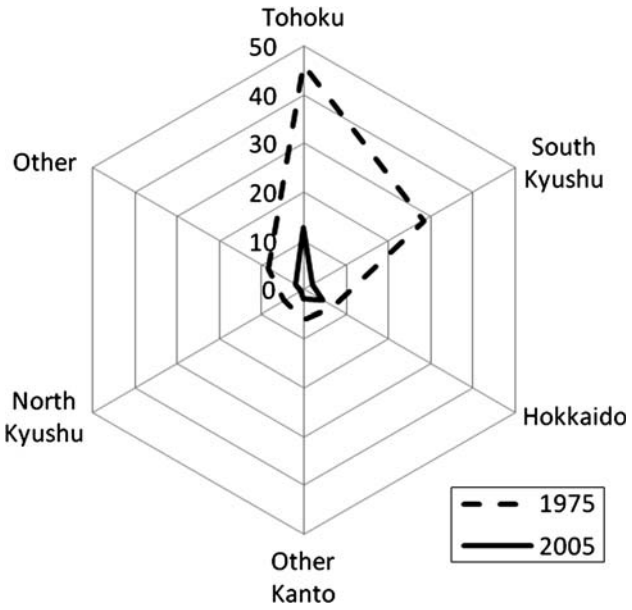

Fig. 10 Total direct area (in 1,000 ha) required to raise domestic beef consumed in Tokyo in 1975 and 2005

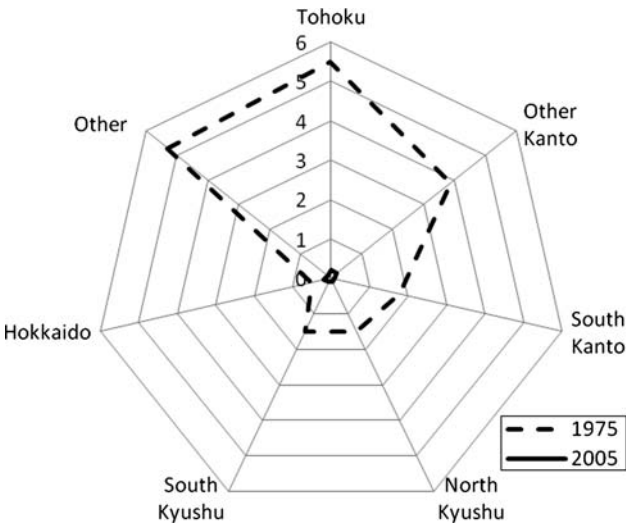

Fig. 11 Total direct area (in 1,000 ha) required to raise domestic pork consumed in Tokyo in 1975 and 2005

Generally speaking, the retail market does not seem to be an important avenue for domestic beef. This can also be validated through figures reported in (MAFF 1971c, 1976c, 1981c, 1986c, 1991c, 1996c, 2001c, 2006c), which account for the number of animals slaughtered in different prefectures of Japan and their final destinations within the country. These statistics show that the number of domestic animal carcasses landing in Tokyo is quite close to the total sold by the wholesale market. Nevertheless, there is an apparent increase in the share of the domestic meat sold in Tokyo's retail market after 2000. This took place with a simultaneous decrease in the amount of imported beef and can be explained by the fears of bovine spongiform encephalopathy (BSE), also known as mad cow disease. Because of BSE, in 2003 the Japanese Government banned beef imports from the US, a country that was, up to that point, one of the largest overseas providers of beef to Japan.

On the other hand, the retail market is a far more important route for pork in Tokyo. While the actual amount of pork it provides to Tokyo residents has remained almost unchanged since 1970, the domestic retail market's overall significance is declining owing to the increasing quantities of imported pork ending up in Tokyo.

Land use

In 2005, Tokyo appropriated less land for the beef and pork consumed within its area than it did in 1975. However, there was an increase in the appropriated land since 2000 owing to the ban of US beef and the overall decrease in imports from other sources (FAO 2008). As per 2005, most land to raise domestic beef is appropriated in Hokkaido, Tohoku, Kyushu and the Kanto area. Figures 10 and 11 present the regions in which more area was appropriated for the meat consumed in Tokyo in 1975 and 2005. Figure 12 summarizes the changes in the overall land appropriated in Japan for the beef and pork consumed in Tokyo and makes a comparison between that land and the area of Tokyo itself. It seems that in the 1970s and early 1980s the area appropriated in Japan to raise the beef and pork consumed in Tokyo was greater than the area of Tokyo itself. However, the increasing meat production efficiency in Japan and the massive increase in imports (refer to the next section) show that an area equivalent to "just" 40% the area of Tokyo is now required. Even though this might be perceived as a positive sign regarding

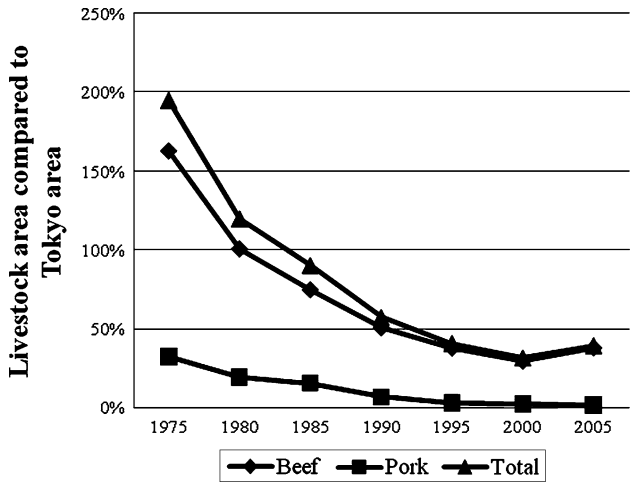

Fig. 12 Livestock area required to raise the livestock consumed in Tokyo compared to the area of Tokyo. Note: 100% denotes an area equivalent to the area of Tokyo

land cover change, it should be put into the appropriate context. Firstly, our calculations do not consider the direct area needed in other countries to produce the imported meat and, secondly, we have not quantified the indirect land requirements (e.g., for cultivating the crops needed for animal feed). It would not be surprising if this area is greater in size than Tokyo, especially considering the potential higher land requirements in other countries where land is not as scarce a production factor as in Japan (e.g., the US or Australia).

Some further important insights on the impact of Tokyo on land use can be identified by exploring the fraction of the farm land that is appropriated for Tokyo's consumption purposes in each of the livestock-producing regions. Tokyo appropriates a large amount of the total direct land used to raise beef cattle in the regions of South Kanto (27.0% in 2005), Other Kanto (19.9% in 2005) and Tohoku (19.0% in 2005) (see Table 1). All three regions are quite close to Tokyo, and this illustrates the continuing reliance of Tokyo on its adjacent areas to provide for its beef. Although it seems that Tokyo is not appropriating a large amount of the direct cattle land on a national scale (9.0% in 2005, down from 15.3% in 1975), it should be kept in mind that its greatest suppliers are consistently areas around it that exhibit some of the highest head-to-ha ratios and are thus the most intensified. The impact of Tokyo on land use for pork on the national scale is pretty much the same as for beef (see Table 2). The main difference is the fact that the wholesale market, which traditionally sells animal carcasses originating from areas close to Tokyo, accounts for just a small fraction of the total pork consumed within the city. As a result, a great quantity of the domestic pork that enters Tokyo is coming already cut or processed from other areas of Japan. Our results show that 9.1% of the land used nationally to raise pork in 2005 is appropriated by Tokyo (down from 15.2% in 1975). However, there is a possibility that these numbers are an underestimation considering that in our calculations, the domestic retail market was obtained as a residual. Nevertheless, Tokyo residents enjoy higher per capita earnings than the national average (MIAC 2008h) and are expected to consume greater amounts of domestic pork despite its generally higher prices when compared with imported meat.

Discussion

It has already been discussed that meat is becoming more prevalent in the Japanese diet. In order to meet this increasing popularity, between 1961 and 2003, domestic production had to be boosted by 247.5% for beef and 517.4% for pork (FAO 2008). However, domestic demand could never have been met by domestic production alone. Imports increased by a staggering 10,839.9% (more than 100-fold) for beef and 111,684.1% for pork (more than a 1,000-fold) since 1961 (FAO 2008). This was possible through the strength of Japan's and, particularly, of Tokyo's economy. This increasing meat demand by Tokyo's residents could only be sustained through a flourishing economy, and indeed, Tokyo's prefectural gross domestic product (GDP) has more than tripled since 1970, as reported by MIAC (2008i). Furthermore, according to MIAC (2008j), as of 2004, Tokyo's prefectural per capita income was 70.6% higher than that of the rest of Japan. These figures are expected to be even higher for the 23 wards of Tokyo that were considered in our study.

The quantity of imported beef overtook domestic production in the early 1990s, while imported pork is closing in to overtake domestic production. This dependence on imported meat is the reason why self-sufficiency ratios for beef and pork decreased dramatically between 1960 and 2003 by 57.0% for beef (from 96.0 to 39.0%) and 43.0% (from 96.0 to 53.0%) for pork (MIAC 2008k). Our results (Figs. 8 and 9) imply that similar amounts of dependency ratios are observed for Tokyo. This growth in imports and decreasing self-sufficiency ratios have important repercussions, which are that more and more land is appropriated overseas to provide for the increasing appetite of Japanese and Tokyoites for meat. Unfortunately, lack of complete datasets concerning the sources of imported meat as well as the land required to raise livestock in other countries rendered the calculation of the land appropriation abroad not feasible.

While meat production cannot be attributed to have caused any direct significant land use/cover change in Japan as a whole, at least in the last 40 years, this does not hold true if we look at the uneven distribution of meat production among Japanese prefectures. A characteristic example is the case of Hokkaido, where the overall amount

of land required for beef production has risen by 185.1% since 1970. Furthermore, it seems that the ban of imported beef from certain countries because of the risk of mad cow disease has resulted, since 2000, in an increasing amount of land being appropriated in that region by Tokyo to an extent not seen since the late 1970s.

Perhaps the main question that arises from our results is why Tokyo has consumed most of its domestic meat and as a result has appropriated large amounts of land from regions such as Tohoku, South Kanto and Other Kanto. The competitive prices of meat originating from these prefectures that has been sold through Tokyo's wholesale market might be the answer. We analyzed the per kg price (in yen) of the meat sold at Tokyo's wholesale market by region as reported in (TMG 1971, 1976, 1981, 1986, 1991, 1996, 2001, 2006a). We also produced a comparison between the fraction of beef sold in Tokyo's wholesale market from different areas of the country and the average prices. Those figures are presented in the electronic supplementary material (Tables 7, 8; Figs. 1–4, respectively).

The beef coming from South Kanto has the lowest price for most of the years studied. Furthermore, beef from Other Kanto has a competitive price throughout the years. In fact, Other Kanto exhibits the highest fractions of beef sold through the wholesale market in those years when price is lower than that of other areas. It does not seem to be a coincidence that Other Kanto's fraction gradually declines after 1985 when the price of beef from that area overtook the average price for Japan. Another important insight that can be provided comes when comparing the prices for domestic and imported meat. Generally speaking, prices for imported beef decreased over time and obtained a steadily competitive advantage in the market. This might explain the increase of beef imports that culminated with imports overtaking domestic production, as has been discussed in previous sections. Interestingly, beef prices went up by 22.0% for domestic and a massive 146.7% for imported beef between 2000 and 2005, which can be explained by the overall decrease in imports following the mad cow disease scare and the inability of the domestic production to meet the domestic demand. Similar conclusions can be drawn for pork given that Tohoku, South Kanto and Other Kanto exhibit competitive prices for all years. Finally, it should be noted that, due to lack of relevant data from the retail market, these prices refer only to meat sold through the wholesale market. Nevertheless, some of these trends are expected to be observed in the retail market as well.

However, despite its great influence, price alone does not seem enough to determine the origin of the meat sold at Tokyo's wholesale market. Preferences and established commercial networks may also play an important role. The region of Hokkaido, for example, has presented very competitive prices for beef when compared to other regions in Japan. Nevertheless, the actual amount of beef produced in Hokkaido and sold at Tokyo's wholesale market has been relatively modest.

Another important observation is that the decrease in the amount of land required to raise animals domestically comes hand in hand with a simultaneous change in the diet of the animals themselves. There has been a gradual decrease in the amount of agricultural land utilized to grow grass (up to 60.6% by area and 66.4% by tonnage since 1970 but falling steadily since the early 1990s) and a much more significant decrease in the land area used to grow other feed crops (down to 52.5% in area and 13.6% by tonnage). Furthermore, there was a 49.4% increase in the tonnage of imported feed crop and forage, which implied increasing land use impacts of Japanese, and subsequently Tokyo's, meat consumption abroad. Most importantly, it implies further dependency of the Japanese livestock industry on other countries.

All these point to the perceived threat of Japan's food security exemplified over the past years and justify the campaign of the Japanese Government for a shift back to the traditional Japanese diet. Finally, the changes in the importance of the retail and wholesale sector, in Japan in general and in Tokyo in particular, reinforce the concerns regarding food security in the city as government control is applied exclusively to wholesales.

Conclusions

Tokyo's population is consuming ever greater quantities of beef and pork. As a result it has been increasingly dependent on meat produced abroad, possibly appropriating ever more land in other countries to provide for its appetite. However, while Tokyo's reliance on meat production from its neighboring prefectures was greater in the past, it is still significant. With food security at stake, and considering that there is not a foreseeable trend towards a decreasing meat demand in Japan, it is important to recover national production, especially in the vicinity of Japan's largest city. For this end, policies and economic incentives at the regional level seem fundamental.

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References

Belsky AJ, Matzke A, Uselman S (1999) Survey of livestock influences on stream and riparian ecosystems in the western United States. J Soil Water Conserv 54:419–431

Bestor T (2004) Tsukiji: the Fish market at the center of the world. University of California Press, Berkeley and Los Angeles
Clay JW (2004) World agriculture and the environment: a commodity-by-commodity guide to impacts and practices. Island Press, Washington, DC
FAO (2008) Food balance sheets. Food and Agricultural Organization, Rome. http://faostat.fao.org/site/502/default.aspx. Accessed July 2008
Galloway JN, Burke M, Bradford GE, Naylor R, Falcon W, Chapagain A, Gaskell J, McCullough E, Mooney HA, Oleson KLL, Steinfeld H, Wassenaar T, Smil V (2007) International trade in meat: the tip of the pork chop. Ambio 36:622–629
Hayami Y (1979) Trade benefits to all: a design of the beef import liberalization in Japan. Am J Agric Econom 61:342–347
MAFF (1971a) Statistics by farm enterprise in animal industry (Keiei Bumonbetsu Noka Tokei Hokokusho). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (1971b) Statistics by type of farm (Noka Chosa Hokokusho). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (1971c) Edible meat circulation statistics (Shokuniku ryutu Toke). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (1976a) Statistics by farm enterprise in animal industry (Keiei Bumonbetsu Noka Tokei Hokokusho). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (1976b) Statistics by type of farm (Noka Chosa Hokokusho). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (1976c) Edible meat circulation statistics (Shokuniku ryutu Toke). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (1981a) Statistics by farm enterprise in animal industry (Keiei Bumonbetsu Noka Tokei Hokokusho). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (1981b) Statistics by type of farm (Noka Chosa Hokokusho). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (1981c) Edible meat circulation statistics (Shokuniku ryutu Toke). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (1986a) Statistics by farm enterprise in animal industry (Keiei Bumonbetsu Noka Tokei Hokokusho). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (1986b) Statistics by type of farm (Noka Chosa Hokokusho). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (1986c) Edible meat circulation statistics (Shokuniku ryutu Toke). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (1991a) Statistics by farm enterprise in animal industry (Keiei Bumonbetsu Noka Tokei Hokokusho). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (1991b) Statistics by type of farm (Noka Chosa Hokokusho). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (1991c) Edible meat circulation statistics (Chikusan Ryutu Tokei). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (1996a) Statistics by farm enterprise in animal industry (Keiei Bumonbetsu Noka Tokei Hokokusho). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (1996b) Statistics by type of farm (Noka Chosa Hokokusho). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (1996c) Edible meat circulation statistics (Chikusan Ryutu Tokei). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (2001a) Statistics by farm enterprise in animal industry (Keiei Bumonbetsu Noka Tokei Hokokusho). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (2001b) Statistics by type of farm (Noka Chosa Hokokusho). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (2001c) Edible meat circulation statistics (Chikusan Ryutu Tokei). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (2006a) Statistics by farm enterprise in animal industry (Keiei Bumonbetsu Noka Tokei Hokokusho). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (2006b) Statistics by type of farm (Noka Chosa Hokokusho). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (2006c) Edible meat circulation statistics (Chikusan Ryutu Tokei). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MAFF (2006d) Annual Report on Food, Agriculture and Rural Areas in Japan. Ministry of Agriculture, Forestry and Fisheries, Tokyo. http://www.maff.go.jp/e/annual_report/pdf/fy2006_rep.pdf. Accessed July 2008
MAFF (2007) Edible meat circulation statistics (Chikusan Ryutu Tokei). Ministry for Agriculture, Forestry and Fisheries, Tokyo (in Japanese)
MIAC (2008a) Area by Land Category (1963–1998). Ministry of Internal Affairs and Communication, Tokyo. http://www.stat.go.jp/data/chouki/zuhyou/01-08.xls. Accessed July 2008
MIAC (2008b) Area by Land Category (1995–2004). Ministry of Internal Affairs and Communication, Tokyo. http://www.stat.go.jp/data/nenkan/zuhyou/y0106000.xls. Accessed July 2008
MIAC (2008c) Intake of Nutrients—Per Capita per Diem (F.Y.1946–1963, C.Y.1964–2004). Ministry of Internal Affairs and Communication, Tokyo. http://www.stat.go.jp/data/chouki/zuhyou/24-01.xls. Accessed July 2008
MIAC (2008d) Farm Households Raising Livestock or Chickens and Livestock or Chickens Raised (1877–2005). Ministry of Internal Affairs and Communication, Tokyo. http://www.stat.go.jp/data/chouki/zuhyou/07-17.xls. Accessed July 2008
MIAC (2008e) Production of raw milk, hen's eggs, chicken and carcass (1894–2003). Ministry of Internal Affairs and Communication, Tokyo. http://www.stat.go.jp/data/chouki/zuhyou/07-18.xls. Accessed July 2008
MIAC (2008f) Population of cities (1920–2005). Ministry of Internal Affairs and Communication, Tokyo. http://www.stat.go.jp/data/chouki/zuhyou/02-09.xls. Accessed July 2008
MIAC (2008g) Population, daytime population and ratio of daytime population to nighttime population of major cities (1965–2000). Ministry of Internal Affairs and Communication, Tokyo. http://www.stat.go.jp/data/chouki/zuhyou/02-08.xls. Accessed July 2008
MIAC (2008h) Average monthly earnings of regular employees by prefectures. Ministry of Internal Affairs and Communication, Tokyo. http://www.stat.go.jp/data/chouki/zuhyou/19-41.xls. Accessed July 2008
MIAC (2008i) Prefectural accounts—68SNA (F.Y.1975–1999). Ministry of Internal Affairs and Communication, Tokyo. http://www.stat.go.jp/data/chouki/zuhyou/03-37-a.xls. Accessed July 2008
MIAC (2008j) Economic growth rate and prefectural income per capita (F.Y. 2000–2004). Ministry of Internal Affairs and Communication, Tokyo. http://www.stat.go.jp/data/nenkan/zuhyou/y0314a00.xls. Accessed July 2008
MIAC (2008k) Self-sufficiency ratio of food (F.Y.1960–2003). Ministry of Internal Affairs and Communication, Tokyo. http://www.stat.go.jp/data/chouki/zuhyou/07-56.xls. Accessed July 2008

Naylor R, Steinfeld H, Falcon W, Galloway J, Smil V, Bradford E, Alder J, Mooney H (2005) Losing the links between livestock and land. Science 310:1621–1622

Otsuka S (1996) Japanese food, fast and present. About Japan series. Tokyo Foreign Press Center, Tokyo

Sakurai A (2004) Stories of the Slaughterhouse. The journal of humanities 33: LXXI-XCIV. Chiba University. http://ci.nii.ac.jp/cinii/servlet/QuotDisp?LOCALID=ART0007286046&DB=NELS&USELANG=en. Accessed 21 July 2008

Stanford C, Bunn HT (eds) (2001) Meat-eating and human evolution. Oxford University Press, Oxford

Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, de Haan C (2006) Livestock's long shadow: environmental issues and options. Food and Agriculture Organization (FAO), Rome

TMG (1971) Tokyo wholesale market annual report (Tokyo-to Chio Oroshiuri Shijo Nenpo). Tokyo Metropolitan Government, Tokyo (in Japanese)

TMG (1976) Tokyo wholesale market annual report (Tokyo-to Chio Oroshiuri Shijo Nenpo). Tokyo Metropolitan Government, Tokyo (in Japanese)

TMG (1981) Tokyo wholesale market annual report (Tokyo-to Chio Oroshiuri Shijo Nenpo). Tokyo Metropolitan Government, Tokyo (in Japanese)

TMG (1986) Tokyo wholesale market annual report (Tokyo-to Chio Oroshiuri Shijo Nenpo). Tokyo Metropolitan Government, Tokyo (in Japanese)

TMG (1991) Tokyo wholesale market annual report (Tokyo-to Chio Oroshiuri Shijo Nenpo). Tokyo Metropolitan Government, Tokyo (in Japanese)

TMG (1996) Tokyo wholesale market annual report (Tokyo-to Chio Oroshiuri Shijo Nenpo). Tokyo Metropolitan Government, Tokyo (in Japanese)

TMG (2001) Tokyo wholesale market annual report (Tokyo-to Chio Oroshiuri Shijo Nenpo). Tokyo Metropolitan Government, Tokyo (in Japanese)

TMG (2006a) Tokyo wholesale market annual report (Tokyo-to Chio Oroshiuri Shijo Nenpo). Tokyo Metropolitan Government, Tokyo (in Japanese)

TMG (2006b) Destination of landings in Tokyo wholesale market. Tokyo Metropolitan Government, Tokyo (in Japanese)

TMG (2007) Nutritional status of Tokyo's residents. Tokyo Metropolitan Government, Tokyo (in Japanese)

Wassenaar T, Gerber P, Verburg PH, Rosales M, Ibrahim M, Steinfeld H (2007) Projecting land use changes in the Neotropics. The geography of pasture expansion into forest. Glob Environ Change 17:86–104

Zhang YK, Schilling KE (2006) Increasing streamflow and baseflow in Mississippi River since the 1940s: effect of land use change. J Hydrol 324:412–422